

Course Learning Outcome #3:

Identify the characteristics of the various transmission media.

- (a) (1 Point) Two antennas are used for LOS transmission. If one antenna is 75 m high and the other is 18.75 m high, what is the maximum distance between the two antennas? Assume  $K = 4/3$ .

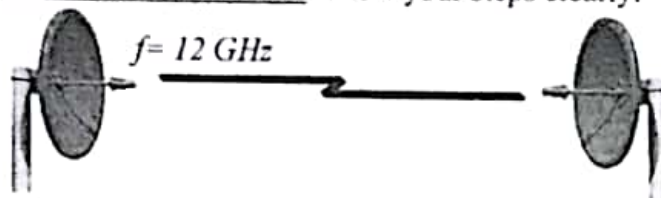
$$\sqrt{\frac{4}{3} \times 75}$$

$$d = 3.57(\sqrt{Kh_1} + \sqrt{Kh_2})$$

$$= 3.57(\sqrt{100} + \sqrt{25})$$

$$d = 53.55 \text{ m}$$

- (b) (1 Point) Two identical parabolic antennas are used for microwave communications at 12 GHz, both of them have 6 m diameter. If the speed of light is  $3 \times 10^8$  m/s, Deduce the gain (G) of each antenna in decibels. Show your steps clearly.



$$6.25 \times 10^{14}$$

$$6.72 \times 10^{14}$$

$$\lambda = \frac{c}{f} \quad G_{dB} = 10 \log_{10} \left( \frac{7A}{\lambda^2} \right) \quad A_e = 0.56A \quad G_{dB} = 10 \log_{10} \left( \frac{4\pi}{\lambda^2} A_e \right)$$

$$\lambda = \frac{3 \times 10^8}{12} = 25000000$$

$$G_{dB} = 10 \log_{10} \left( \frac{7 \times 6}{(25000000)^2} \right) = 10 \log_{10} \left( \frac{42}{6.25 \times 10^{14}} \right)$$

$$10 \log_{10} (6.72 \times 10^{14}) = 131 \text{ dB}$$

- (c) (1 Point) Two identical parabolic antennas are used for microwave communications with carrier wavelength ( $\lambda$ ) of 0.025 m. Given the gain (G) of each antenna is 50 dB and the distance between these two antennas is 14000 m, deduce the free space loss in decibels. Show your steps clearly.

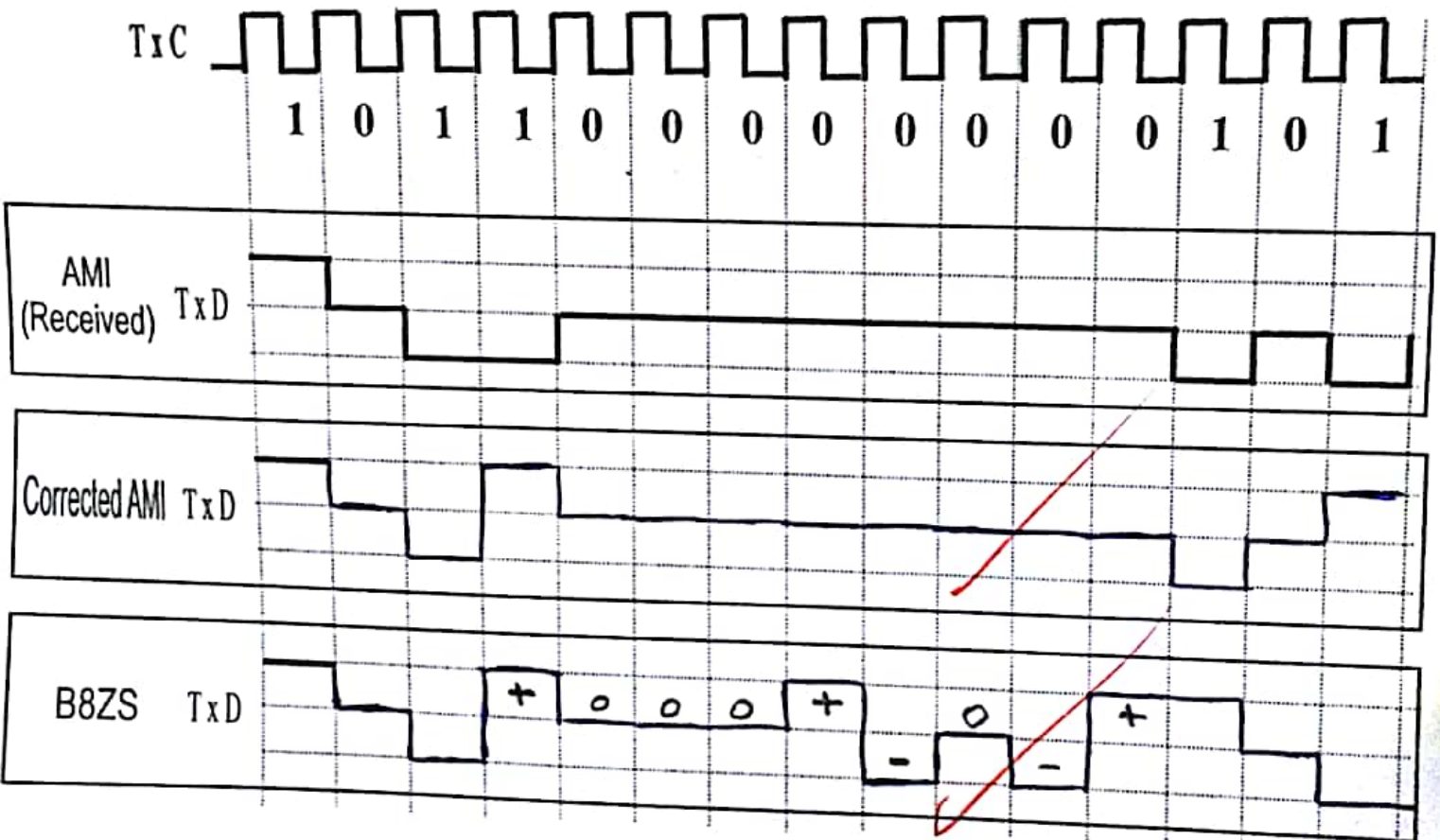
$$L_{dB} = 20 \log(4\pi) + 20 \log d - 20 \log \lambda - G_{dB} - G_{dB}$$

$$L_{dB} = 20 \log(4\pi) + 20 \log(14000) - 20 \log(0.025) - 50 - 50$$

$$= 21.98 + 82.92 + (-32.04) - 50 - 50$$

$$L_{dB} = 86.94 - 50 = 36$$

- (a) (3 Points) The bipolar-AMI waveform representing the binary sequence 1011000000101 is transmitted over a noisy channel. If the AMI received signal is shown in the following figure:

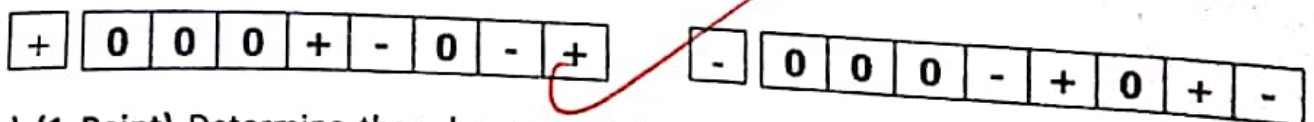


Answer the following questions:

- (i) (½ Point) If errors do exist, circle the error positions on the received AMI signal.

- (ii) (½ Point) If errors do exist, draw the corrected AMI signal.

- (iii) (1 Point) If the same binary sequence was transmitted using B8ZS, determine the output of the digital encoder.



- (iv) (1 Point) Determine the advantage of the received B8ZS signal over the AMI signal.

AMI we have problem with 0s Now with B8ZS fix a lack of Synchronization.



(2 Points) Complete the following table to compare among the encoding schemes.

Hint: You need to write either YES or NO. For each incorrect answer, 1/2 point will be deducted.

Encoding Scheme	DC Component	Lack of Synchronization	Error Detection	Noise Immunity	Clock Extraction	Cost (Higher signal rate)
AMI (1 Point)	<del>None</del>	<del>long sequence of 0s</del>	<del>yes</del>	<del>No</del>	<del>yes</del>	<del>No</del>
Manchester (1 Point)	<del>None</del>	<del>None</del>	<del>yes</del>	<del>yes</del>	<del>yes</del>	<del>yes</del>

(c) (2 Points) The theoretical Bit Error Rate (BER) for various encoding techniques is illustrated in the following chart. Assume that AMI encoding is used and the bandwidth efficiency is 2 bps/Hz. If we are interested to have  $10^{-4}$  BER, deduce the signal to noise ratio (SNR) in decibels.

Hint:

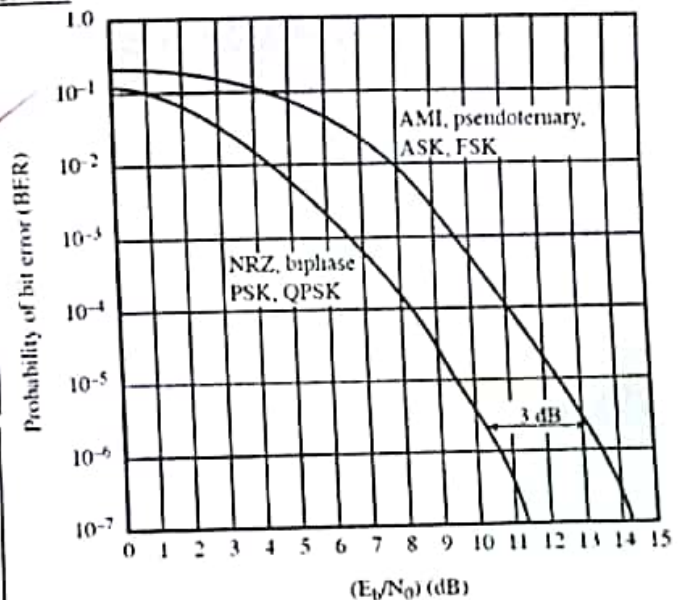
$$E_b/N_0 = 11$$

$$(E_b/N_0)_{dB} = ? \quad 10 \log_{10} E_b/N_0 = 10^{1.1} = 12.58 \text{ dB}$$

$$E_b/N_0 = ? \quad 11$$

$$12.58 \text{ dB}$$

$$(R/B)_{dB} = ? \quad 10 \log_{10} 2 = 3.01 \text{ dB}$$



$$(S/N)_{dB} = 10 \log_{10} (E_b/N_0 \times R/B) \rightarrow (S/N)_{dB} = (E_b/N_0)_{dB} + (R/B)_{dB}$$

$$(S/N)_{dB} = (E_b/N_0)_{dB} + (R/B)_{dB}$$

$$(S/N)_{dB} = 12.58 + 3.01$$

$$= 14.01 \text{ dB}$$

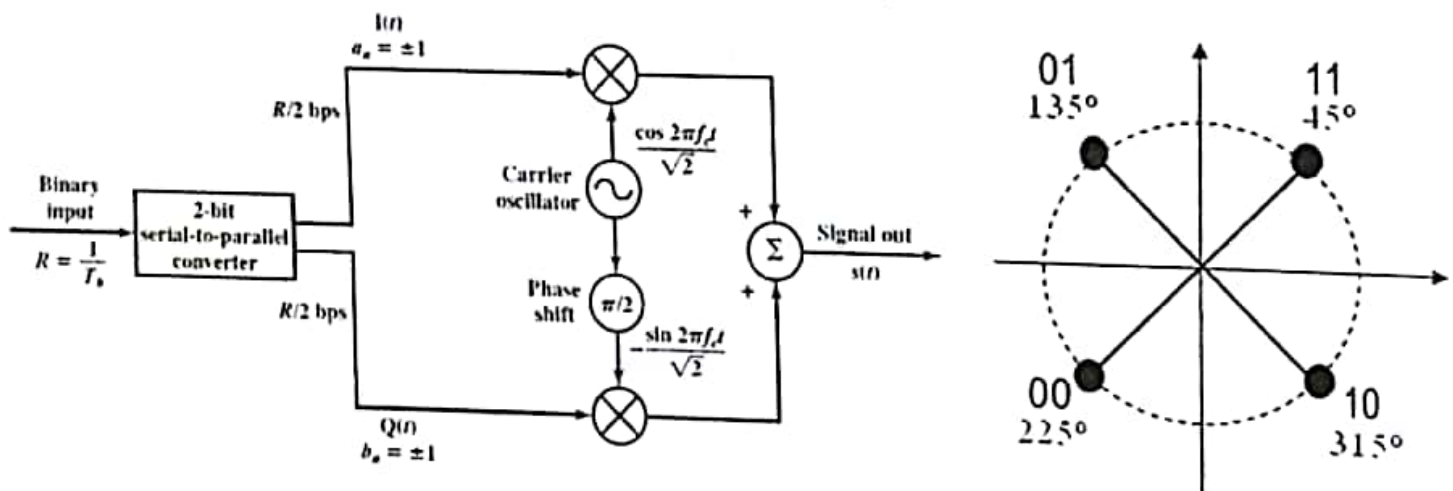
## 2. (5 Points) Answer the following questions related to DIGITAL DATA to ANALOG

### SIGNAL encoding:

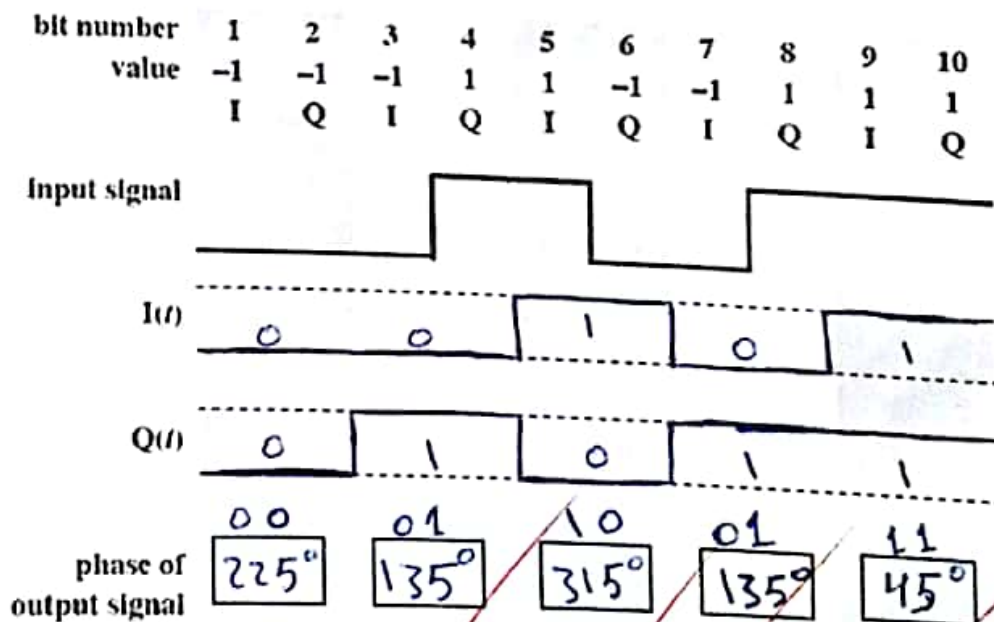
(a) (1 Point) Obtain the baud rate for a 64,000 bps 16-QAM signal ( $M=16$  levels)?

$$R = \frac{R_b}{\log_2 M} = \frac{64000}{4} = 16000 \text{ baud}$$

(b) (2 Points) Given the following QPSK modulation system:



Complete the following figure by finding out  $I(t)$ ,  $Q(t)$ , and phase of the transmitted signal.



(c) (2 Points) A digital signal is characterized by the following frequencies.  
The carrier frequency  $f_c = 400$  kHz and the difference frequency  $f_d = 20$  kHz.

(i) (1 Point) Calculate the frequency for each of the 3-bit combinations.

$$f_i = f_c + (2i - 1 - M) f_d, 1 \leq i \leq M$$

$$f_c = 400 \text{ kHz}, f_d = 20 \text{ kHz}, M = 8$$

i	1	2	3	4	5	6	7	8
binary	000	001	010	011	100	101	110	111
$f_i$ kHz	? 260 kHz	? 300 kHz	? 340 kHz	? 380 kHz	? 420 kHz	? 460 kHz	? 500 kHz	? 540 kHz

(ii) (1 Point) Calculate the total bandwidth required and the supported data rate.

$$W_d = 2Mf_d \quad W_d = 2 \times 8 \times 20 = 320 \text{ kHz}$$

$$R = 2mf_d \quad R = 2 \times 3 \times 20 = 120 \text{ kbp's}$$

$f_1$	$400 - 7 \times 20$	260 kHz
$f_2$	$400 - 5 \times 20$	300 kHz
$f_3$	$400 - 3 \times 20$	340 kHz
$f_4$	$400 - 20$	380 kHz
$f_5$	$400 + 20$	420 kHz
$f_6$	$400 + 3 \times 20$	460 kHz
$f_7$	$400 + 5 \times 20$	500 kHz
$f_8$	$400 + 7 \times 20$	540 kHz



(Points) Answer the following:

### SIGNAL encoding:

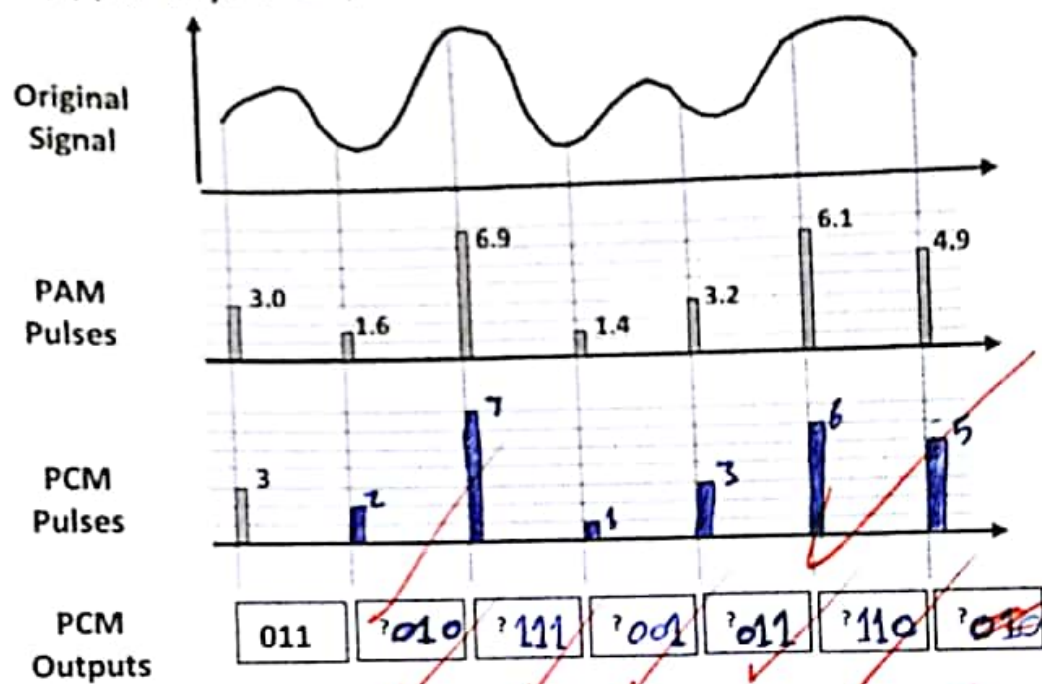
- (a) (1 Point) Determine the PCM bit rate for a signal with 3100 Hz bandwidth (from 300 Hz to 3400Hz) and with 32 quantization levels.  $M=5$

$$\text{bit rate} = B_w = 2 \cdot f_c = 5 \text{ baud}$$

- (b) (1 Point) Complete the following figure by showing both:

(i) (½ Point) PCM pulses.

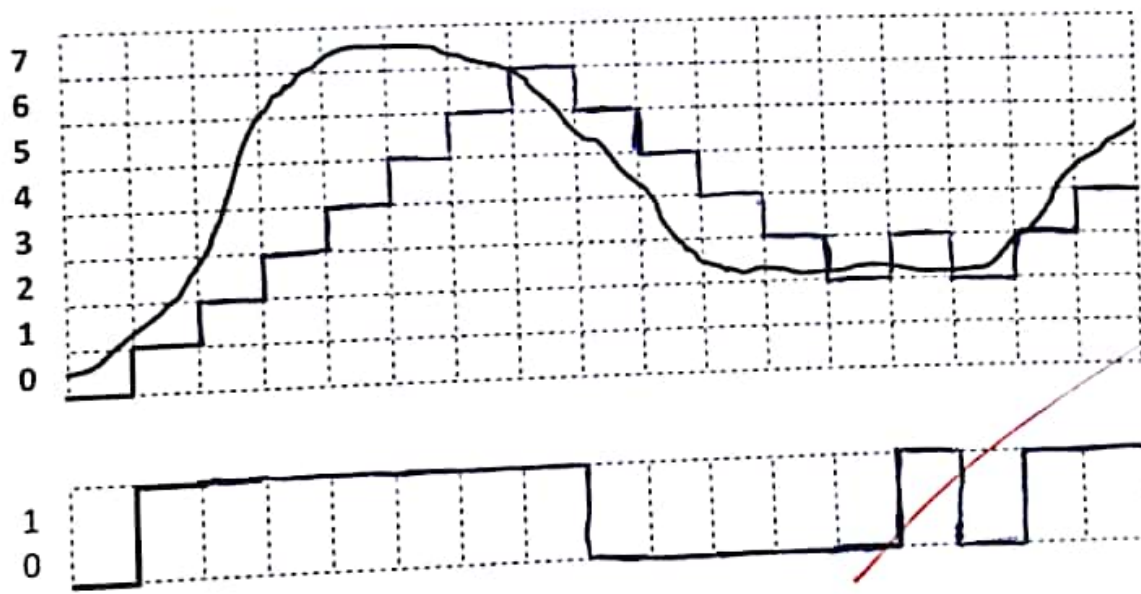
(ii) (½ Point) PCM output.



- (c) (2 Point) Using delta modulation and the following analog waveform:

(i) (1 Point) Draw the staircase function.

(ii) (1 Point) Show the DM output.



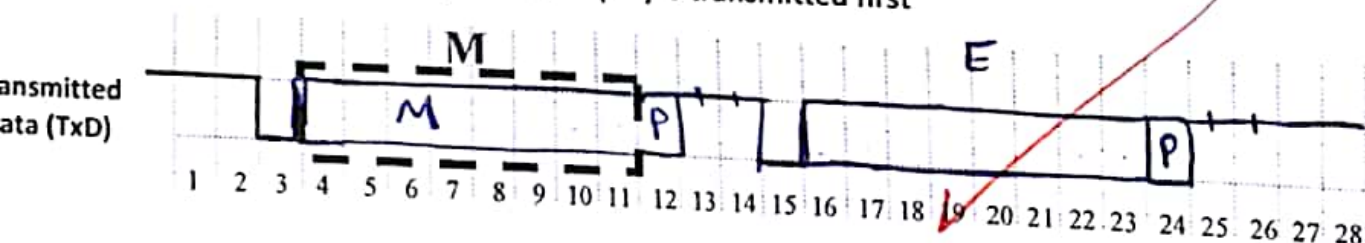
(a) (2 Points) A transmission system uses asynchronous transmission. It is assumed that each transmitted character has the following format:

- The idle state is logical 1 value. Its length is variable and is zero bits if characters are transmitted back-to-back
- One start bit with logical 0 value
- 8 data bits
- One odd parity bit
- Two stop bits with logical 1 values

(i) (1 Point) If the word "ME" is to be transmitted (with letters back-to-back, i.e. no delay in between), fill in the following figure for the resulting character stream.

Hints:

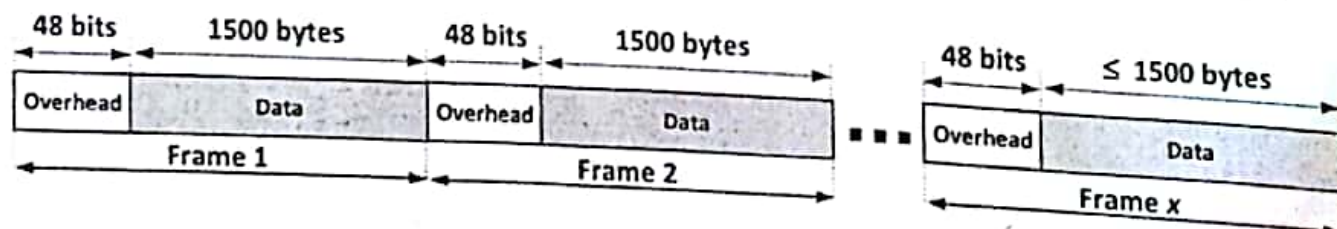
- No need to include framing characters such as STX and ETX
- Given M = 01001101; E = 01000101
- The least significant bit (lsb) is transmitted first



(ii) (1 Point) Compute the link efficiency ( $\eta$ ).

$$\eta = \frac{8}{8(1+1+2)} = \frac{8}{12} = 0.66$$

(b) (1 Point) Suppose a file of 10,000 bytes is to be sent. Assume that the data are sent in frames. Each frame consists of 1500 bytes (at maximum) and overhead of 48 control bits per frame. Calculate the total overhead in bits using synchronous communication.



$$\text{Number of Frame} = 7 \text{ frames}$$

$$\text{overhead in bits} = 7 \times 48 = 336 \text{ additional bits}$$

# Question 4 (3 Points) Error Control

Course Learning Outcome #6:

Understand the principles of error detection and control

(a) (1 Point) Compute the odd and even parities for the following 8-bit message:

1 1 0 1 0 0 1 1

? 0

Odd Parity

1 1 0 1 0 0 1 1

? 1

Even Parity

(b) (2 Points) The following message 10011011 is to be transmitted across a data link using CRC for error detection. A generator polynomial  $x^4 + x^3 + 1$  is to be used. Find the contents of the transmitted frame  $T(x)$ .

$$\begin{array}{r}
 11001 \quad 100110110000 \\
 \underline{11001} \phantom{0000} \\
 -10100 \phantom{0000} \\
 11001 \phantom{0000} \\
 \underline{11001} \phantom{0000} \\
 -11011 \phantom{0000} \\
 11001 \phantom{0000} \\
 \underline{11001} \phantom{0000} \\
 -00101 \phantom{0000} \\
 00000 \phantom{0000} \\
 \underline{00000} \phantom{0000} \\
 -01010 \phantom{0000} \\
 00000 \phantom{0000} \\
 \underline{00000} \phantom{0000} \\
 -10100 \phantom{0000} \\
 11001 \phantom{0000} \\
 \underline{11001} \phantom{0000} \\
 -11010 \phantom{0000} \\
 11001 \phantom{0000} \\
 \underline{11001} \phantom{0000} \\
 -00110 \phantom{0000} \\
 00000 \phantom{0000} \\
 \underline{00000} \phantom{0000} \\
 0110 \leftarrow R(x)
 \end{array}$$

$$\rightarrow T(x) = \underbrace{10011011}_{T(x)} \quad 0110$$